CD R&D on Optical Links for Detector Data Transmission

Sept. 13, 2010
Fermilab

All Experimenter's Meeting

Alan G. Prosser
Electronic Systems Engineering
Fermilab

CD R&D on Optical Links for Detector Data Transmission

Outline:

- Versatile Link Common Project
- Free Space Optical Transmission
- New Optohybrids for CMS Pixel Detector Upgrade
- U.S. Based R&D Program for Optical Links

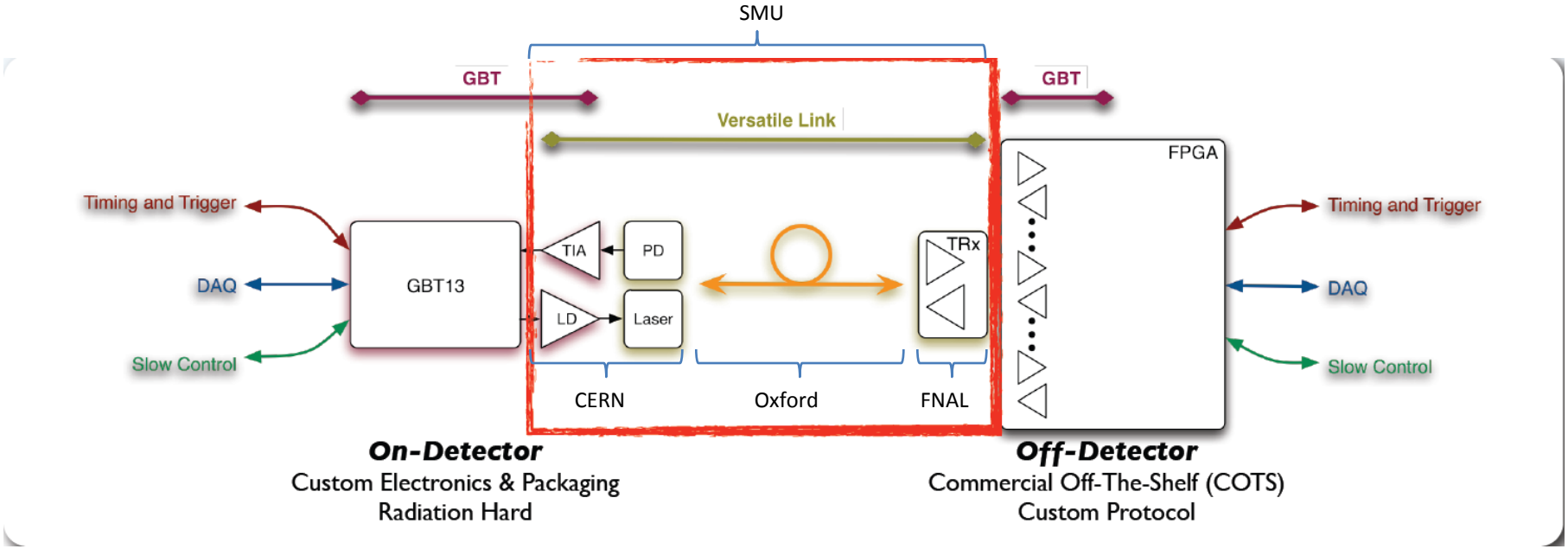
Participants:

Fermilab Computing Division:

- Mark Bowden
- John Chramowicz
- Orlando Colon
- Simon Kwan
- Alan Prosser

Versatile Link Common Project

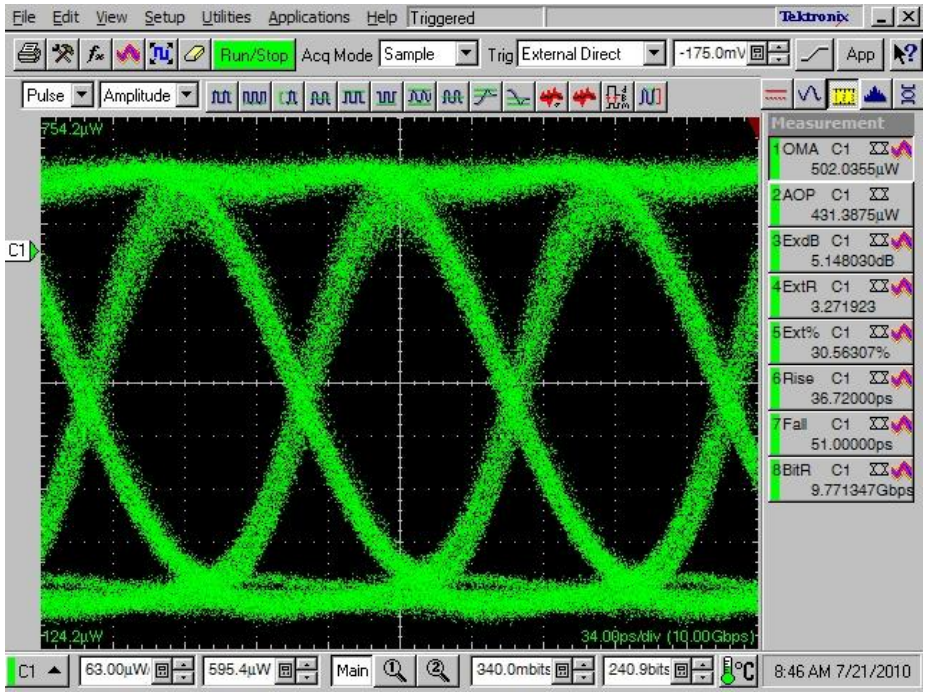
Versatile Link: CERN-organized common project for ATLAS and CMS
Goal: "Development of a general purpose optical link which can cover all envisioned transmission applications: a versatile link" @ data transfer rates of up to 5 Gbps.

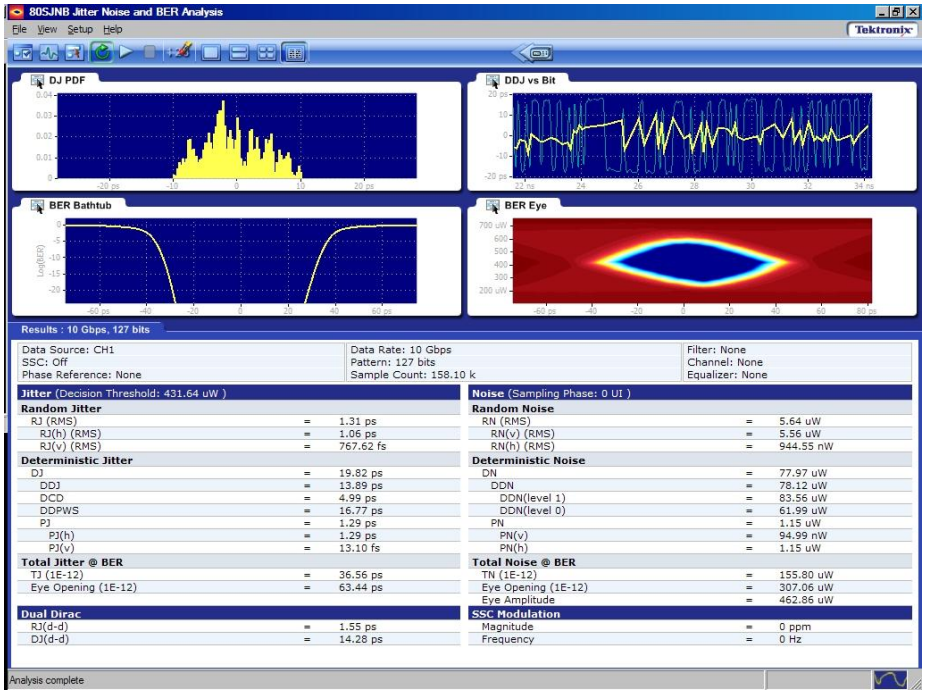


Work Package 1.1 (Southern Methodist University)
Point to Point Architecture and System Engineering
Work Package 2.1 (CERN)
Front End Components (Versatile Transceiver)
Work Package 2.2 (Fermilab)
Back End Components (COTS, Off Detector Components)
Work Package 2.3 (Oxford University)
Passive Components

Source: "Versatile Link Status Report"
Jan Troska
CMS Tracker Upgrade Meeting
April 24, 2009

Optical Transceiver Test Measurements





Industry Standard Measurements and Apparatus

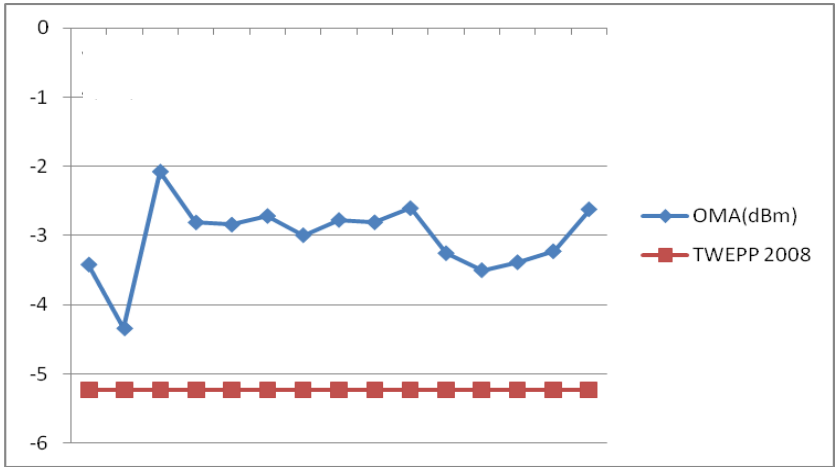
Eye Diagram Measurements:

Optical Modulation Amplitude
Extinction Ratio
Rise/Fall Times

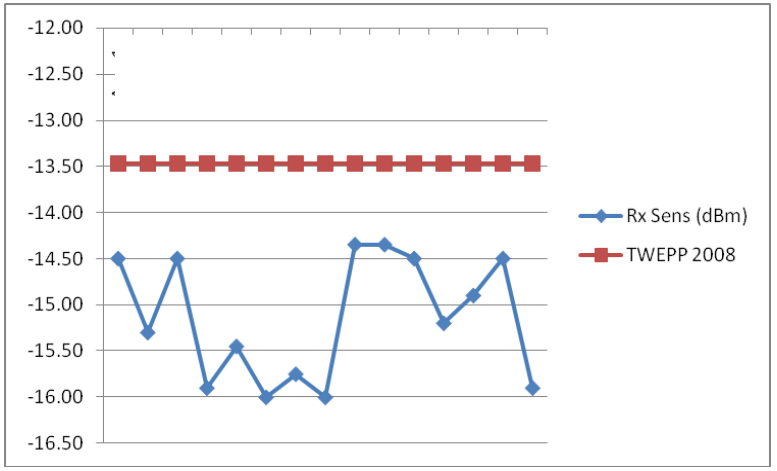
Jitter Analysis:

Deterministic Jitter (including decomposition)
Random Jitter (Gaussian, unbounded)
Eye Opening @ 10^{-12} BER

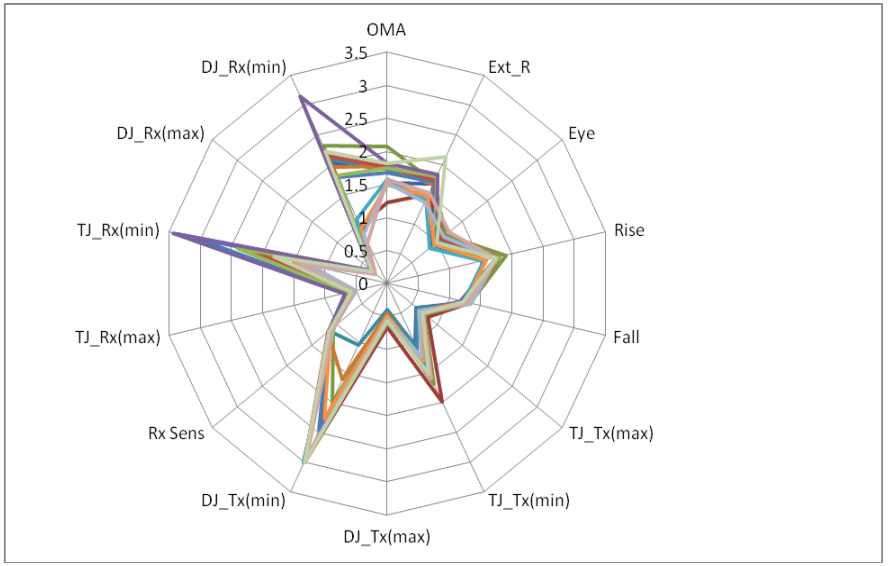
Versatile Link SFP+ Transceiver Measurements



Transmitter Measurements
(each point is a different vendor or device)



Receiver Measurements
(each point is a different vendor or device)



Radar Plots
(each axis is a measurement, each color a device)

Data Collected at:

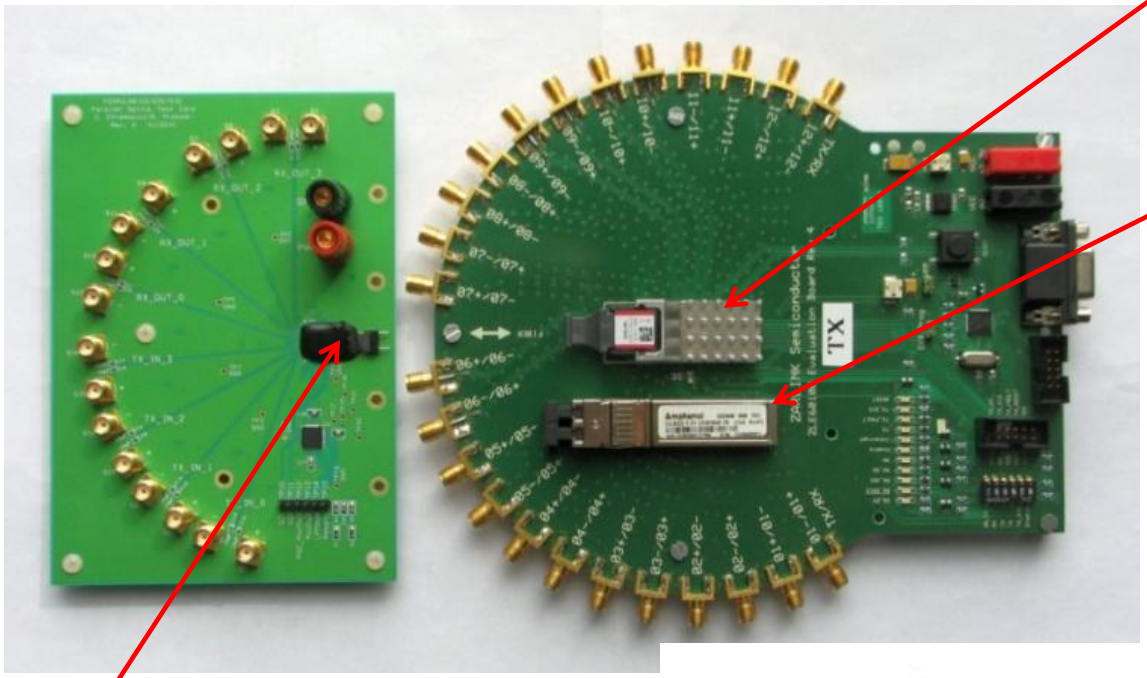
5 Gbps
6.25 Gbps
10 Gbps

Parallel Optics – Package Evolution

- Emerging Standards (100 GbE) Driven by Telecom and Storage
- Off the shelf and prototype devices evaluated
- High speed, parallel communications in multiple footprints
- For HEP: High Channel Count, Easier Cable Management
  Reduced Board Area (including connectors)
- Next Step: Develop µTCA Based Application Board (Q2, 2011)

SNAP12 Transmitter
(12 channels, 2.7 Gbps/channel)

SFP+ Single Channel
Transceiver
(10 Gbps)



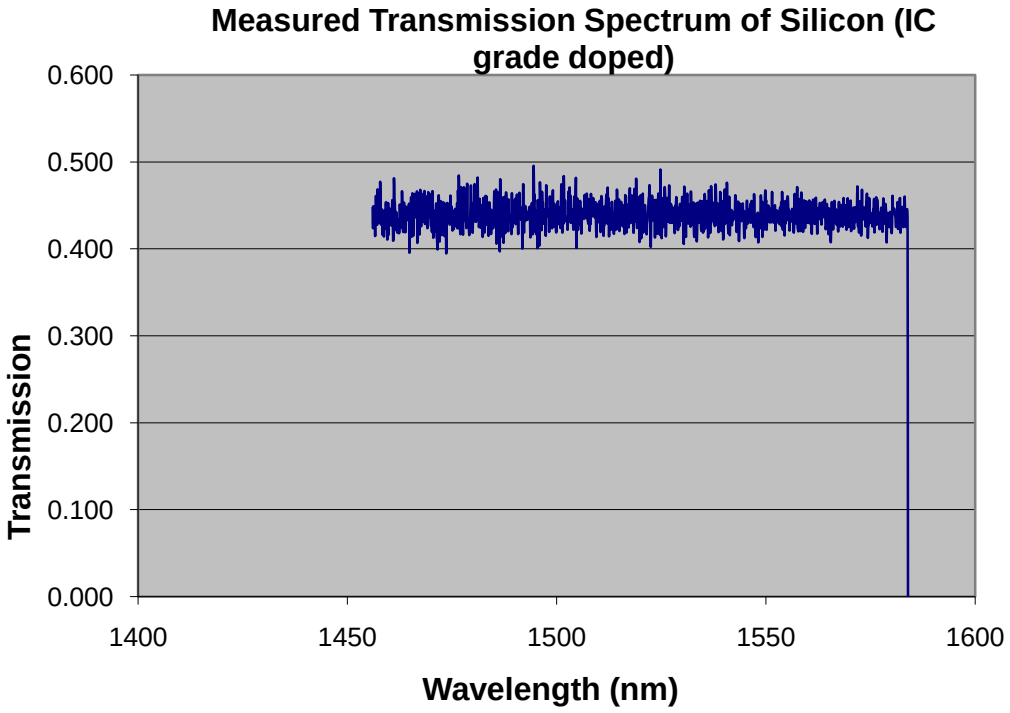
Parallel Optical Engine Transceiver
(4 channels, 6.25 Gbps/channel)
(Efficient PCB Applications,
Lower Electromagnetic Noise)

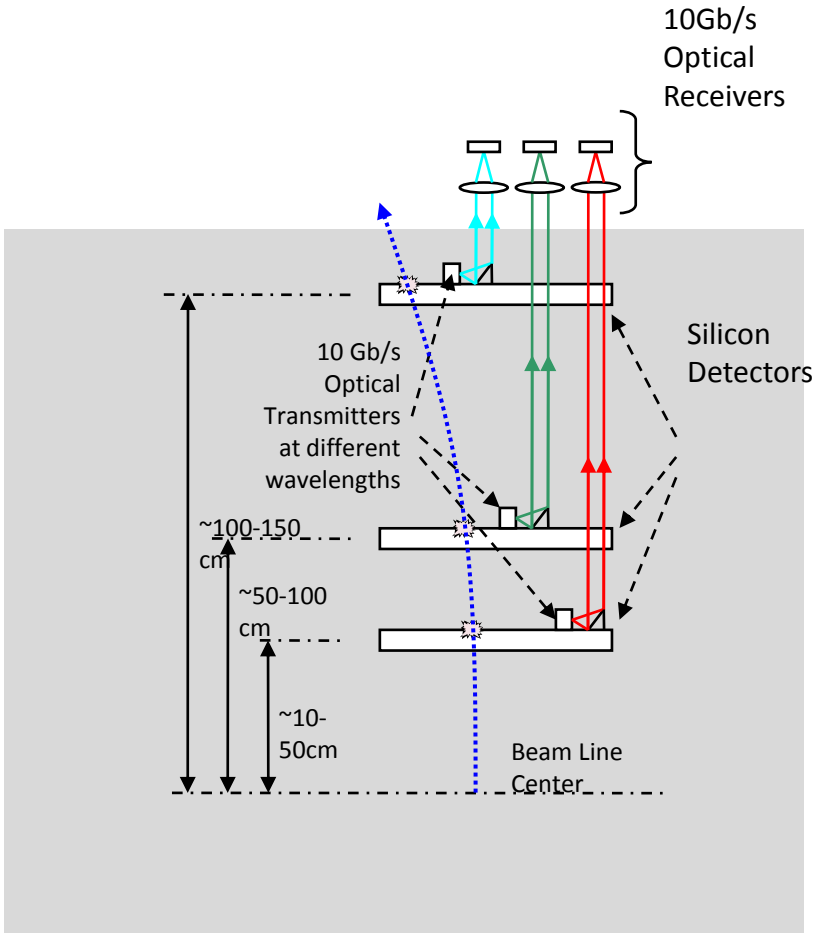
Parallel Optical Engine Transmitter
(12 channels, 12.5 Gbps/channel,
1 Qtr, 2011, BGA Reflow
Assembly, Optics Included)

Cable-less Free Space Optical Data Transmission

(with Vega Wave Systems (T. Moretti, A. Sugg) and FNAL PPD (T. Liu))

- Motivation:
  - Reduce material budget
  - Work within rigid space constraints



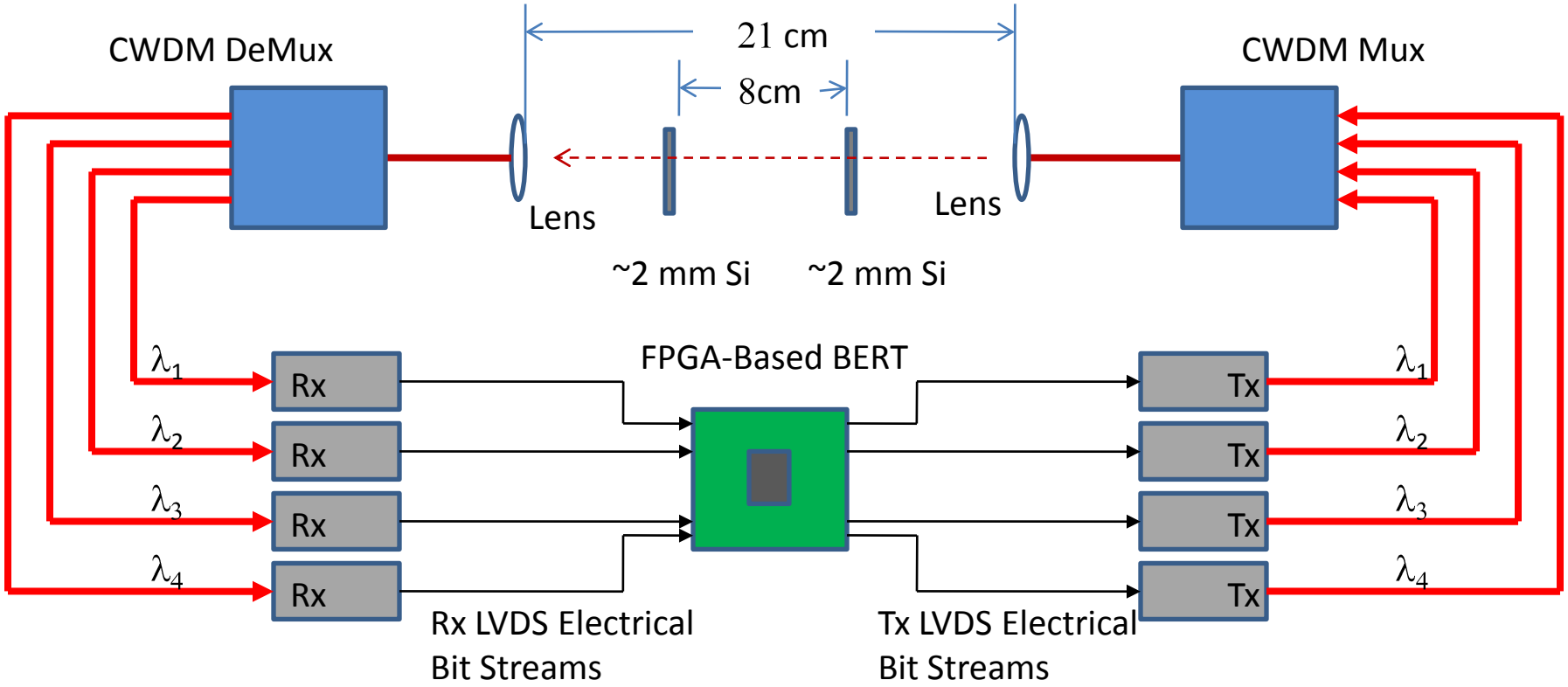


- Optical fibers removed from detector volume
- Transmission through free space or silicon

CWDM/Free Space Bit Error Rate Testing
Proof Of Concept

λ_1 = 1470 nm
λ_2 = 1490 nm
λ_3 = 1510 nm
λ_4 = 1530 nm

CWDM: Coarse Wavelength Division Multiplexing



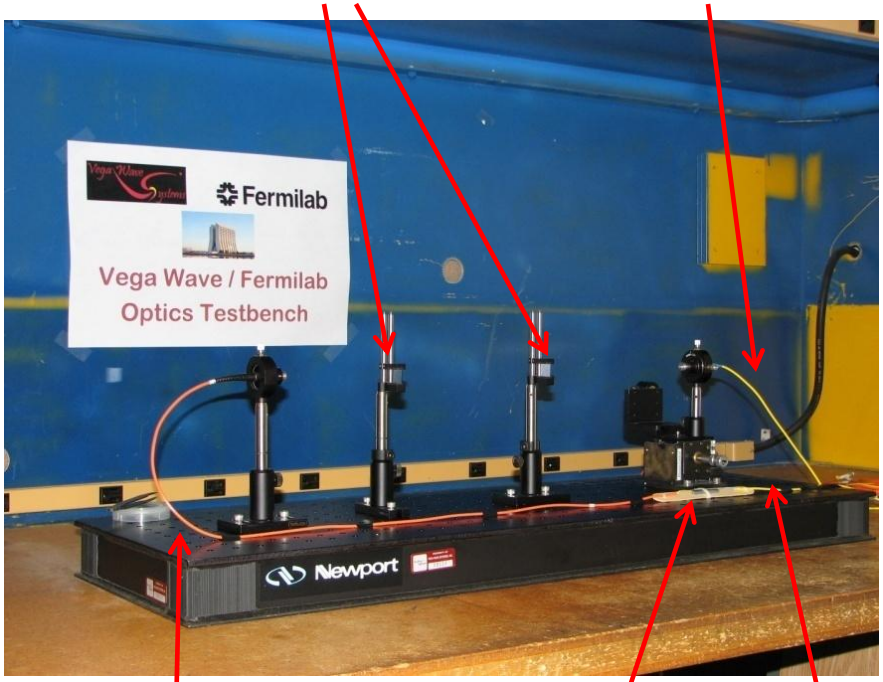
Next Step: Evolve the Optical Design for Detector Applications

CWDM/Free Space Optics Lab Test
Proof of Concept

Free-Space Optics Lab Test Bench

Silicon Slices

Single-mode Fiber (Tx Mux Side)



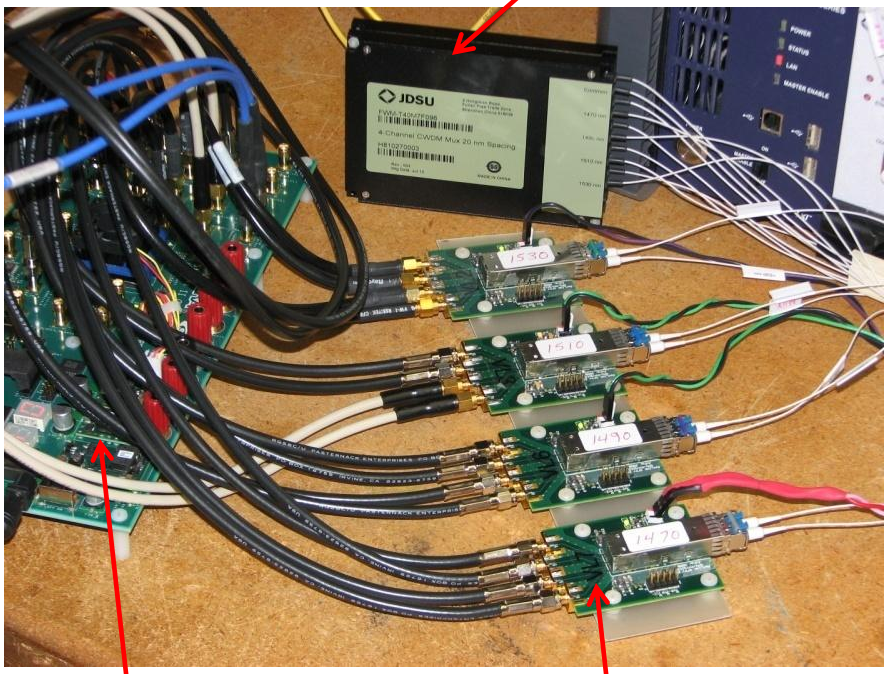
Multi-mode Fiber

Mode Converter

Single-mode Fiber (Rx DeMux Side)

Free-Space Optics TRx Group

JDSU CWDM Mux and DeMux Units



Altera Stratix II Signal Integrity Kit

TRx Group (4 SFP Devices)

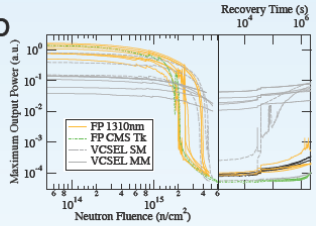
Operating error free for over 48 hours at 1 Gbps on all 4 four channels

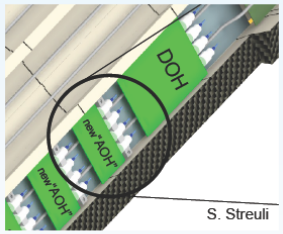
CMS Pixels Phase One OptoHybrid Approach

Moving towards new Pixel OH

CERN

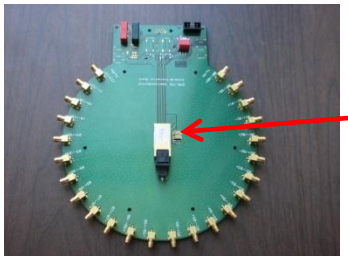
- Profit from work within Versatile Link project to identify a sufficiently radiation resistant packaged Laser (TOSA)
  - Present Laser die no longer produced and not available
- Design and build a prototype OH to check signal integrity, matching of new laser to existing laser driver (LLD)
  - Dimensionally compatible with current mechanical design
  - Include ALT?





FNAL

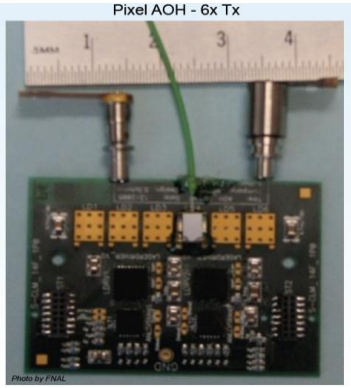
- Fully characterize design inc. system test, thermal management
- Produce, Test, QA

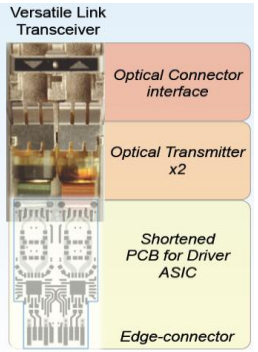


1310 nm Receiver Array (SNAP12)
- Tested at 2.5 Gbps at FNAL
- CERN testing at 800 Mbps indicates device will work at these rates for FED

Need:
- Current Laser No Longer Available
- Upgrades Will Require New Devices to Be Identified

Requirements:
- Rad tolerant
- Digital Transmission at Rates Up To 640 Mbps





Next Steps:
- System Performance Testing of CERN-designed OH with FED Array Receiver
- Develop Qualification Test Plan

U.S. Based R&D Program on Optical Data Links

Optical Data Transmission Workshop (hosted by CD, Aug. 19, 2010):

Participants:

- National Labs (ANL, FNAL)
- Universities (UChicago, UMinnesota, Ohio State, SMU)
- Industry (Tyco, Altera)

Summary:

- Activities were presented and discussed
- Vendors described current products and roadmaps

Next Steps:

- Identify Common Areas of Interest
- Define Scope and Focus of the Collaboration
- Working Group Meeting to be Held During Detector R&D Workshop at Fermilab (1st Week of October, 2010)